N66-22344
(ACCESSION NUMBER)
54
(PAGES)
CR-54924
(NASA CR OR TMX OR AD NUMBER)

(THRU)
1
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(CATEGORY)

FACILITY FORM 602

NASA-CR-54924

DEVELOPMENT OF ELECTRICAL SWITCHGEAR FOR SPACE NUCLEAR ELECTRICAL SYSTEMS

QUARTERLY PROGRESS REPORT NO. 5

For Period: December 4, 1965 Thru March 4, 1966

EDITED BY A. H. POWELL

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NAS 3- 6467 - PHASE I

SPACE POWER AND PROPULSION SECTION
MISSILE AND SPACE DIVISION
GENERAL ELECTRIC
CINCINNATI, OHIO 45215

GPO PRICE $ ______

CFSTI PRICE(S) $ ______

Hard copy (HC) 3.00

Microfiche (MF) .50

ff 653 July 65

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Edited by:

A.H. Powell
Program Manager

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Contract NAS 3-6467

Technical Management
NASA-Lewis Research Center
E.A. Koutnik

SPACE POWER AND PROPULSION SECTION
MISSILE AND SPACE DIVISION
GENERAL ELECTRIC COMPANY
CINCINNATI, OHIO 45215

FOREWORD

This report describes work which has been completed during the period from Dec. 4, 1965 to March 4, 1966, the present status, and the future plans for the effort being performed by the General Electric Company under Contract NAS 3-6467 from the National Aeronautics and Space Administration. The objective, as outlined in the contract, is to develop and design ground prototype AC circuit breakers and DC engine contactors, suitable for, and tested under, expected launch and space requirements. The Breakers will be rated 1000 volts, 600 amperes, 2000 cps, while the DC Contactors will have a rating of 10,000 volts, 10 amperes.

Management of the program for General Electric Company has been assigned to A.H. Powell, Manager - Electrical Systems, Space Power and Propulsion Section. Consulting Engineer is R.N. Edwards, SPPS. Project Engineer for over-all design is E.F. Travis of the Research and Development Center in Schenectady. Project Engineer for Capsule Assembly and Welding Techniques is W.R. Young of the Space Power and Propulsion Section. Contributors to this report, in addition to Messrs. Edwards, Powell, Travis, and Young include G. Gati, G. Rouse, and S. Thompson of SPPS.

Mr. E.A. Koutnik of the National Aeronautics and Space Administration is the Technical Manager for this contract.

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I. INTRODUCTION

This program, a continuation of the Electrical Switchgear investigation which was completed under Contract NAS 3-2546, is designed to provide detail background and knowledge for final flight hardware for space nuclear power systems of 1 to 4 megawatts capacity. The breaker is to have a continuous rating of 600 amperes and an interrupting rating of 1200 amperes, at 1000 volts, 1000 to 3000 cps. The contactor is designed to carry 10 amperes continuously and to interrupt the same value at 10,000 volts DC.

Over-all development effort on this contract will result in building and testing ground prototype breakers and contactors which can withstand limited (1000 hour) endurance testing (with normal current flowing) in a typical space environment of 1000°F and 10^{-6} torr (or lower) pressure. The samples are also to demonstrate their interrupting ability at high temperature, and, finally, to provide data on their ability to withstand expected launch (mechanical) conditions of shock, vibration, acoustic, and acceleration loadings.

Program Management is centered in the Space Power and Propulsion Section of the General Electric Company in Evendale. The major development and design work has been done at the Research and Development Center in Schenectady with technical assistance from various laboratories and personnel within the Company. Final assembly of the actuators (mechanism) is being done at R&DC while the interrupter unit, including the vacuum capsule assembly and outgassing is being done at SPPS. All vacuum environment testing will be done at SPPS while mechanical tests will be performed at Schenectady (vibration and shock) and the RSD Mechanical Testing Laboratory (acoustic and acceleration) in Philadelphia.

II. SUMMARY

During the fifth quarterly period of the Switchgear Program the actuators were assembled and placed in test, the interrupter units were trial assembled and two vacuum capsules were assembled and in the process of bake-out and seal-off, when a small leak was discovered which initiated detail recheck of the design. In the test activity, all major items for the interruption power supply were procured, and a check and bake-out of the endurance test oven was successfully completed.

Detail information concerning the hardware and the test activity will be given under the Major Section headings (Interrupter, Actuator, Test Facilities & Plans, etc). Up to the point of final vacuum capsule bake-out there had been no insurmountable problems. However, the leak which has developed will require study, and possibly design changes, which could affect the start of tests. Therefore, this problem will receive major attention.

Delivery of some vital parts such as high temperature springs, flexural pivots, and ion pump support parts has delayed some of the assembly, and the effort and procedures needed to complete the vacuum capsules has been greater than expected on the first unit. However, subsequent units, once the techniques have been established, are being more quickly processed.

It now appears that solution to the capsule leak problem may require additional part procurement, but in the meantime, the possibility of making meaningful endurance tests with available devices will be explored. Procedures for the testing in the oven and vacuum tank have been established and proven by the successful bake-out test of the oven. Interrupting test plans and facilities are well advanced and will be completed so that these tests can be started during the next quarterly period.

III. VACUUM INTERRUPTER

The vacuum interrupter includes a supporting shell, heat transfer and insulating parts, and terminals with current-carrying members, to mount and attach the vacuum capsule. The capsule, the heart of the breaker and contactor, and the supporting members (interrupter unit) will be discussed in the following sections.

A) Vacuum Capsule

The vacuum capsule, shown in a cross-section sketch in Figure 1, has been assembled and baked-out, but seal-off has not yet been completed because a small leak was discovered at the lower ceramic-to-metal seal.

The assembly procedure involved leak checking of the ceramic assembly, brazing of the molybdenum contacts to the end disks and flanges, leak checking again, and welding by the inert gas process of the end flanges to the bellows and ceramic assemblies. Figures 2 and 3 show the end flange with assemblies which were brazed together as described in Appendix A, Part B. Figure 4 shows the complete assembled capsule with assembly described in Appendix A, Part C. The short tube to which the ion pump is attached projects through the lower flange (left side of picture). At this point in the fabrication, the assembly was again leak checked and three of the four capsules showed no leak on the helium leak detector at a sensitivity of 1×10^{-10} std. cc of air. Figure 5 shows the rotatable fixture which was used in the argon filled chamber for the welding.

The fourth assembly failed during the welding by having a crack develop in the lower spinning of the ceramic unit. Figure 6 shows the welded joint which became irregular at the point shown when impurities (probably titanium left from the ceramic-metal sealing) caused the weld arc to "blow-out" and require repair. The crack in the spinning developed at the repair point, and lengthened up to about 2" around the spinning. An enlarged view of cross-sections of the end spinning, Figure 7, show that in manufacture the material had been thinned down excessively and the welding stress was apparently great enough to open up the section. The ceramic assembly will be replaced.

The next step in the capsule assembly involved combining of the ion pump parts and attachment to the capsule tube. The ion pump is surrounded by a sealed chamber which will circulate air from outside the test tank to keep the pump and its magnet at a suitable temperature. Figure 8 shows the parts of the pump enclosure, including the top shell, the magnet, inside air hose support, and at the bottom of the photograph, the outer shell to which the return air (flexible) hose is attached.

The pump and housing is supported on the lower flange by a bracket and the pump tube is welded to the capsule tube, as shown in Figure 9. In making the joint, the parts were carefully positioned, the tube ends tacked together, and then welded in argon to provide a vacuum tight joint. Following this assembly, the complete unit was leak-checked and passed O.K. However, when the small leak was detected during bake-out, a review of the test procedure indicated that the part was flooded with helium (from a tube and then a probe) but not "bagged". Therefore, a very small leak (in the order of 1×10^{-9} std. cc per sec) may have been present and gone undetected, or the leak may be dependent on stresses developed during weld assembly and have developed over a period of time.

Investigations into the problem has been started and further work on the capsules will be held up until more data is available.

B) Interrupter Unit

The vacuum capsule is supported inside the interrupter unit shell, as shown in cross-section drawings in previous quarterly reports and as shown for the AC Breaker in Figure 10. The DC unit is of similar design except that radiators are not required because of the low current ratings.

The radiators and inside surface of the AC shell have been coated with plasma sprayed iron titinate coating. Figure 11 shows the three coated parts.

Both the AC and DC Interrupter Units have been "trial" assembled with one of the completed capsules, and necessary minor adjustments have been made to insure proper assembly when the final sealed capsule is available.

Thermocouples made of a platinum/platinum-rhodium wire combination have also been prepared in the proper lengths,so they can be attached at final assembly of the units. At the time of assembly, a nickel wire will also be attached to the midpoint of the capsule (the ring which supports the "floating" shield) for use in the high potential testing.

IV. ACTUATOR

The actuator, or mechanism, for operating the vacuum capsule has been assembled. The first unit made by R&DC has been received by SPPS. The second unit has been assembled with closing, tripping, and latching coils and is at present being checked out at R&DC.

Figure 12 shows the complete actuator in the closed position. The actuator in the open position is shown in Figure 13. Initial operation using the operating coils indicates the movement and latching of the toggle is satisfactory. Some minor adjustments are being made and then a series of check tests are planned to determine closing and tripping speeds. To make these tests a contact wipe spring is being mounted in a fixture to be fastened to the bottom of the actuator to simulate the expected contact closing force and travel.

The over-all actuator weighs 25.2 pounds. The weight of the moving parts is 3.95 pounds. The weight of the AC breaker moving parts is 4.21 pounds, while the DC moving parts (no radiators required) weigh 2.38 pounds. Thus, the three counterbalance springs which are designed to provide a total force of 10 pounds when the actuator is in the open position must also counterbalance the moving parts. The total force for the three springs, for all land based tests, is as follows:

AC Breaker = 10# + 4.21# + 3.95# = 18.16#

DC Contactor = 10# + 2.38# + 3.95# = 16.33#

Suitable spacers for use with the springs which are made of Inconel X and have adequate length to handle both loads, are now being made.

A calibration curve for the opening spring (for vacuum operation of the switchgear) is shown in Figure 14. It indicates the force-deflection relationship, which is useful up to solid height conditions (the configuration in which it was "heat set"). Figures 15 and 16 show the calibration (force-deflection) relationship for the contact wipe springs, and are included for information purposes. Again, these are made of Inconel X and "heat set" for use in 1000°F total temperature.

V. TEST FACILITIES AND PLANS

The test activity for the Program has been in the planning stages for some time, but during the last quarterly period, actual test work started through set-up and bake-out of the heater oven. This test work, along with details of the planning work for all hardware tests, will be discussed in this section.

A) Test Oven Assembly and Bake-out

The heat run and endurance tests will be conducted at SPPS in an ultra-high vacuum tank, using a special heater oven to provide the $1000^{\circ}F$ environment. The last quarterly report (#4) included a sketch of the tank, oven, and specimens in their expected locations (see Figure 10 of the 4th Quarterly Report). The oven assembly was completed early in this period, and assembled in the tank as shown in Figure 17 for initial outgassing. This illustration shows the oven top in place and all connections complete to the feed-throughs, just before the tank lid was put in place.

For this phase of the test program, a series of thermocouples were located as indicated in Figure 18. Typical values of temperatures and pressures obtained during the test are given in Table I.

To start the test, the tank was closed and pumped down to 10^{-7} torr. The pumpdown was accomplished by first using large sorption pumps, and when the pressure was down to one micron, the quartz lamps were energized and the oven temperature raised to initiate outgassing. Also, a "cold finger" located in the bottom of the tank was filled with liquid nitrogen to improve gas collection.

TABLE I

SUMMARY OF DATA FROM OVEN OUTGASSING TEST

Data		Jan. 24		Jan. 25			Jan. 26			
		1600	2400	0700	1400	2200	0600	1050	1230	1900
T.C. Number	1	1010	1037	1230	201	395	1213	1307	597	201
	4	910	1152	1187	201	499	1072	1187	597	201
	6	891	1072	1072	176	499	1010	1081	519	176
	10	891	1204	1195	226	319	1046	1230	598	226
	11	1081	1178	1195	226	373	1117	1230	598	226
Value is in ^{o}F (Refer to Figure 6 for Location)	12	901	1178	1195	226	330	1046	1230	598	226
	13	519	761	752	136	238	676	771	373	150
	14	579	827	827	122	214	799	827	373	136
	15	499	752	752	122	201	637	733	384	189
	16	539	827	827	150	214	752	836	478	176
	17	395	695	676	136	189	618	695	427	163
	18	938	1152	1152	189	437	1064	1169	559	189
	19	752	1010	1001	189	352	901	1001	539	189
	20	974	1247	1247	201	489	1117	1256	559	214
1) Variac No.	10	14	16.5	16.5	0	7.5	13.0	16.4	0	0
Current in Amps)	12	6	8.5	8.5	0	6.0	8.6	8.6	0	0
	13	6	5.0	5.0	0	5.5	8.6	7.8	0	0
Tank Pressure		$11 x 10^{-3}$	$5 x 10^{-3}$	$3 x 10^{-3}$	$< 10^{-6}$	$3.7 x 10^{-8}$	$1.0 x 10^{-7}$	$1.3 x 10^{-7}$	$3.8 x 10^{-8}$	$2,0 x 10^{-8}$
Remarks		Test started @ 1200	Sorbtion Pumps Only	Lamp Pr. Off @ 0720	Ion Pump On	Lamp Pr. on at 1730	Lamp Pr. increased @ 0800	Lamp Pr. Off @ 1100		Test Terminated at 2215

1) Variac #10 controlled one bank (one third) of vertical slat lamps.
#12 controlled bottom slat lamps.
#13 controlled top slat lamps.

When the outgassing started to decrease after the oven slats had been held at $1100^{\circ}F$, the lamps were turned off, the oven temperature decreased, and pressure went low enough so the 1000 liter/second ion pump would start. With the ion pump running, pressure continued to decrease so the oven temperature was again raised (the "cold finger" continuing to be used) until a pressure of 2×10^{-7} torr was obtained with the oven slats at $1100^{\circ}F$. After several hours at this condition, the results were considered satisfactory and the test was terminated. The tank will be left closed until installation of the switchgear for the heat run test to start.

B) Heat Run and Endurance Test

The heat run and endurance test is planned to run for 1000 hours, with one AC Breaker and one DC Contactor mounted in the oven in the vacuum tank, which will provide a $1000^{\circ}F$ and 10^{-6} torr (or lower) pressure. The last quarterly indicated the positioning of the 32 thermocouples which will be used on the hardware, plus the 16 additional TC's which will monitor the oven heat sink and air line temperatures.

Thermocouples have been prepared and will be mounted at the selected points on the switchgear, along with the lead for the high potential check test, as the interrupter (with vacuum capsule) is attached to the actuator. The ion pump air line will also be completed and the assembled units will be mounted on the copper heat sink plate. All final assembly work will be done with white gloves, using ultra-sonically cleaned parts, on a laminar flow clean bench in the SPPS clean room.

When the units are mounted and ready for installation in the vacuum tank, the tank will be opened (refer to Part A above), and the oven power leads and thermocouple connection checked out and rearranged in accordance with the planned set-up. The heat sink with the hardware will be mounted on the oven base using four stainless steel rod supports, the air lines for the ion pumps and heat sink installed, power leads and hi-pot connections installed, thermocouples connected and checked out. When all these items are properly set, the oven top and then the tank lid will be installed and the test started.

The major item required for the test power has been the high frequency low voltage supply for the AC Breaker which will have 600 amperes flowing during the endurance test. A special transformer was obtained with a 3 volt secondary, but this proved inadequate in preliminary tests. Subsequently, a replacing transformer with a 6 volt secondary, plus a special design of "co-ax" conductor for use in the tank, has been proved satisfactory for the program.

The special high current conductor is shown in sketch form in Figure 19. Every effort has been made to keep down inductance loops and obtain a minimum voltage drop. Testing of the new transformer has been completed, and after building and attaching the necessary bars to interconnect the secondary coils and water cooled connection for attachment to the feed-throughs, a series of tests were run to check over-all characteristics. The results of the tests, using special high frequency C.T.'s and meters, is given in Appendix B. The results indicated that the Behlman adjustable frequency power supply, with the new high current stepdown transformer, will provide adequate power.

C) Interruption Tests

The power supply for the interruption tests has been planned and will be built in a movable cabinet. The circuit one line diagram is shown in Figure 20, and details of the study leading to the design and selection of components are given in the following exerpts of a report by Mr. R.N. Edwards.

The AC power supply for the interruption tests consists of six capacitors, arranged for variable tuning connections, plus a variable air-core inductor, designed for high "Q" and long circuit decay times. The required 15 millisecond decay time (to 80% of initial value) at the highest frequency required by the contract (3,200 cps) may require the addition of compensating coils at the ends of the reactor winding, but initial test results should be obtained before this complication is introduced. The required capacitance range for tuning from 1,000 to 3,200 cps is 191 to 60 microfarads.

The calculated tuning connections, on a nominal basis, for the frequency steps required (and the 0.833 ohm level corresponding to 1,200 amperes at 1,000 volts) is tabulated below.

Tuning Connections for AC Tests

Frequency	1,000	1,500	2,000	2,500	3,000	3,200	cps
Capacitance	191.0	127.3	95.5	76.4	63.7	59.7	fd
Inductance	132.6	88.4	66.3	53.0	44.2	41.4	H

The three copper tape wound inductance coils, two wound clockwise, one wound counterclockwise (back wound section) will involve the following material specifications: - 13-3/4" I.D., 18-1/4" O.D. coils, wound from ten strands of 0.021" thick by 5" wide copper sheet, interleaved with 0.002" insulation tape between layers, and .025" tape turn insulation, 8 turns per coil.

The proposed DC power supply now makes use of a high energy capacitor bank, arranged to discharge through a suitable circuit into a 1,000 ohm load resistor (and the switchgear under test) to provide a nearly constant output current during the current carrying period of the test (15 milliseconds) and a recovery voltage with an appropriate rate increase to the open circuit value of 10,000 volts. A simple R-C circuit will be employed for the required discharge energy level of only about 1,825 joules, with an initial stored energy of 6,300 joules, which will limit the initial current and voltage decay to less than 20%. The equipment will use two capacitor units, rated 6 KV, 175 microfarad, which will be connected in series, for 12 KV (87.5 microfarad total rating) to discharge through a 1,000 ohm resistor.

A sketch of the side view of the proposed power supply cabinet is included as Figure 21. Major components such as capacitors, coils, shunts, resistors, and shorting switches, along with the cabinet are either on order or have been received. Assembly will start early in the next period. Test procedures are also being developed for review, and will be available in the next report.

D) Mechanical Tests

Arrangements have been completed for the mechanical tests which are to be made with the samples used for the endurance tests. After the endurance test, coils will be added, the units adjusted and mechanically operated for 100 close-open cycles, and then sent to test.

The AC Breaker unit will be vibration and shock tested at the Research and Development Center in Schenectady. Detail test specifications will be prepared as soon as requirements for the device and its mounting location are confirmed for the expected launch vehicles.

The DC Contactor sample will, after installation of coils and bench check-out, be sent to Philadelphia for acoustic and acceleration tests.

VI. SCHEDULE

It appears that during the next quarterly period the heat run and endurance test will be completed and the interruption test equipment built, tests planned, and possibly will be started.

Assembly of the vacuum capsules has tanen longer than expected, and the problem of the small leak must be solved, but it should be possible to do so within the next month. All required material for the switchgear units is now in hand, the power supply components are nearly all available, and plans and direction are either issued or in process for all test activity.

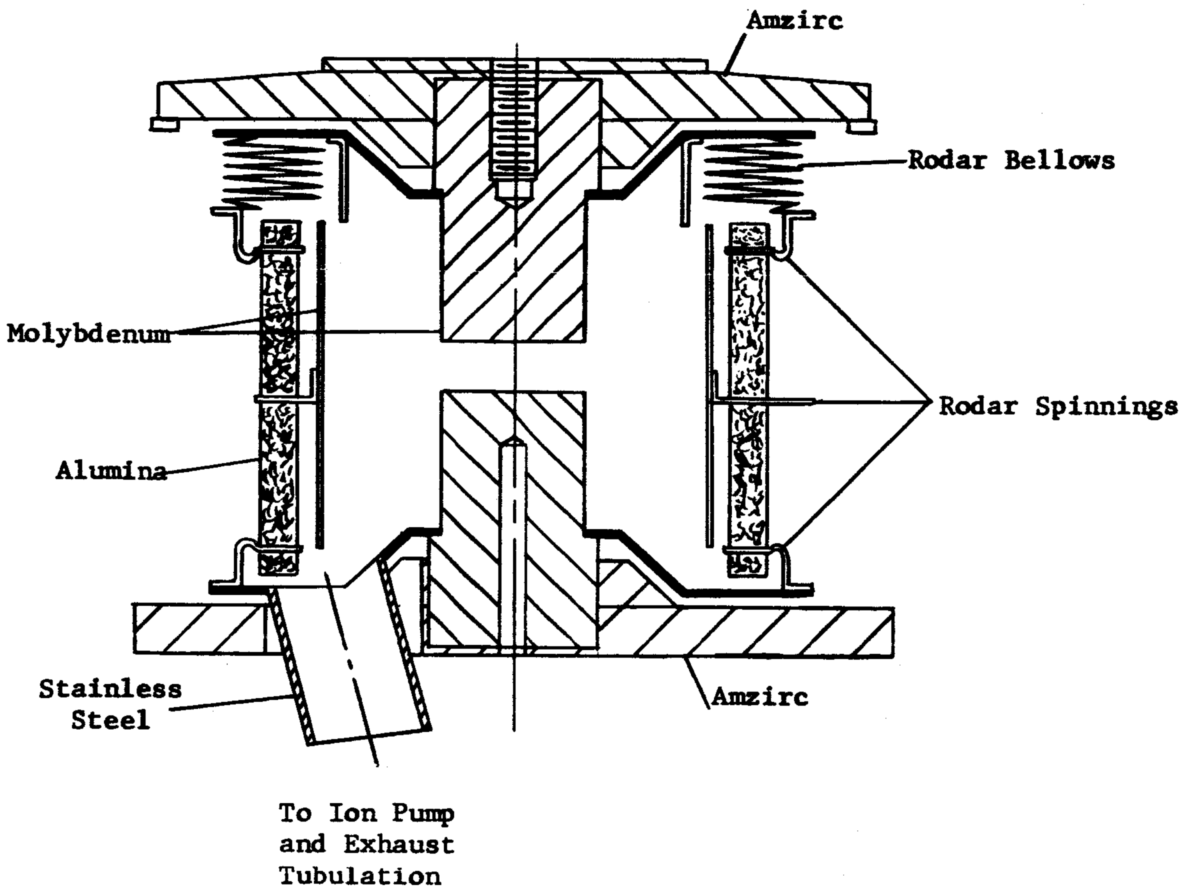


Figure 1. Sketch of Vacuum Capsule for Both AC Breaker and DC Contactor.

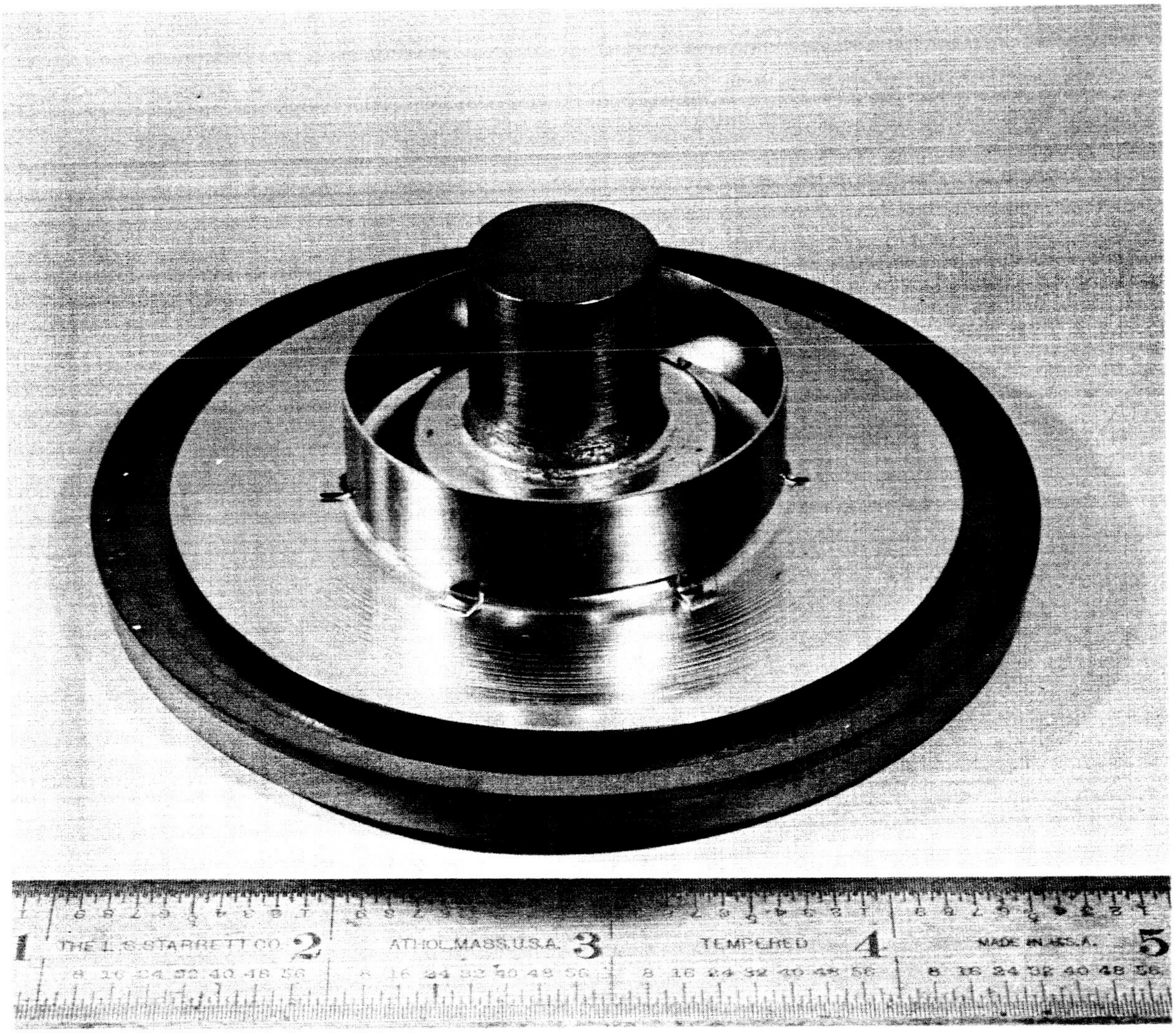


Figure 2. Upper Flange Sub-assembly for Vacuum Capsule Including Molybdenum Contact, Arc Shield, Rodar End Dish, and Amzirc Flange.

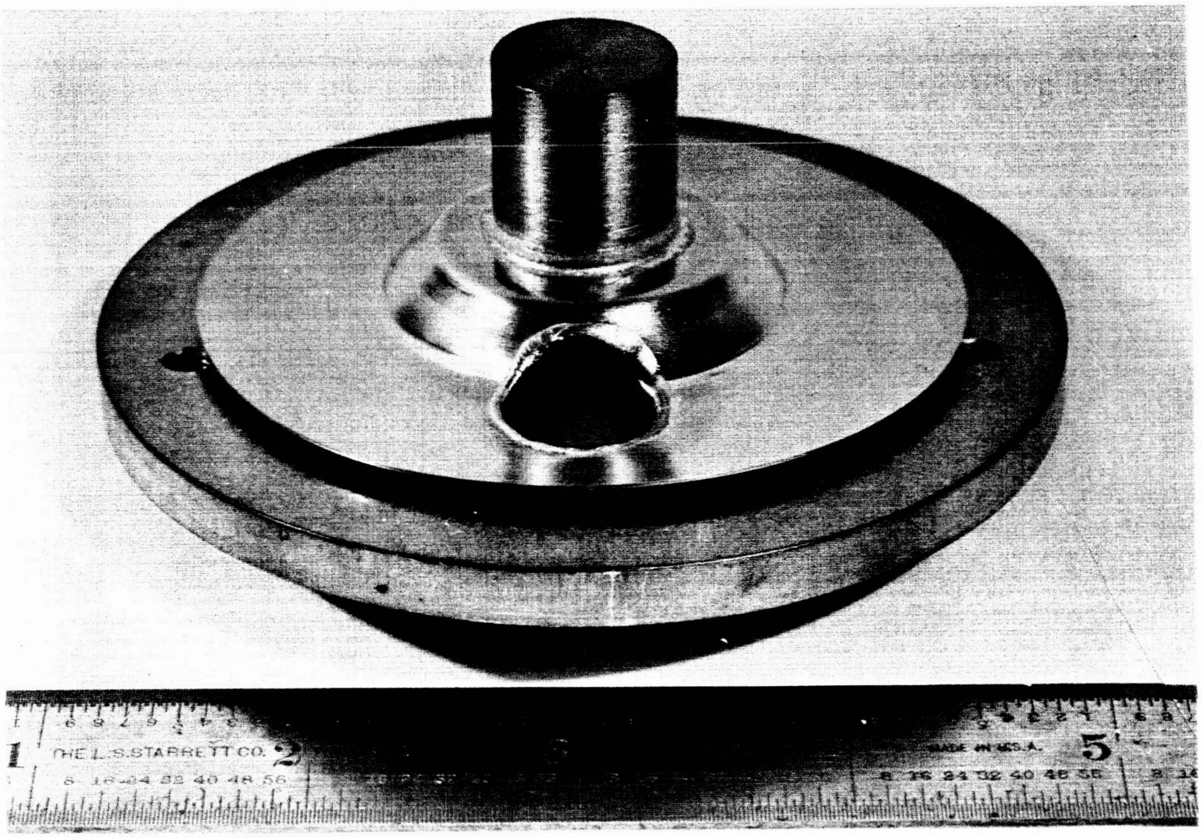


Figure 3. Lower Flange Sub-assembly for Vacuum Capsule Including Molybdenum Contact, Rodar End Dish with Tube for Ion Pump Connection, and Amzirc Flange.

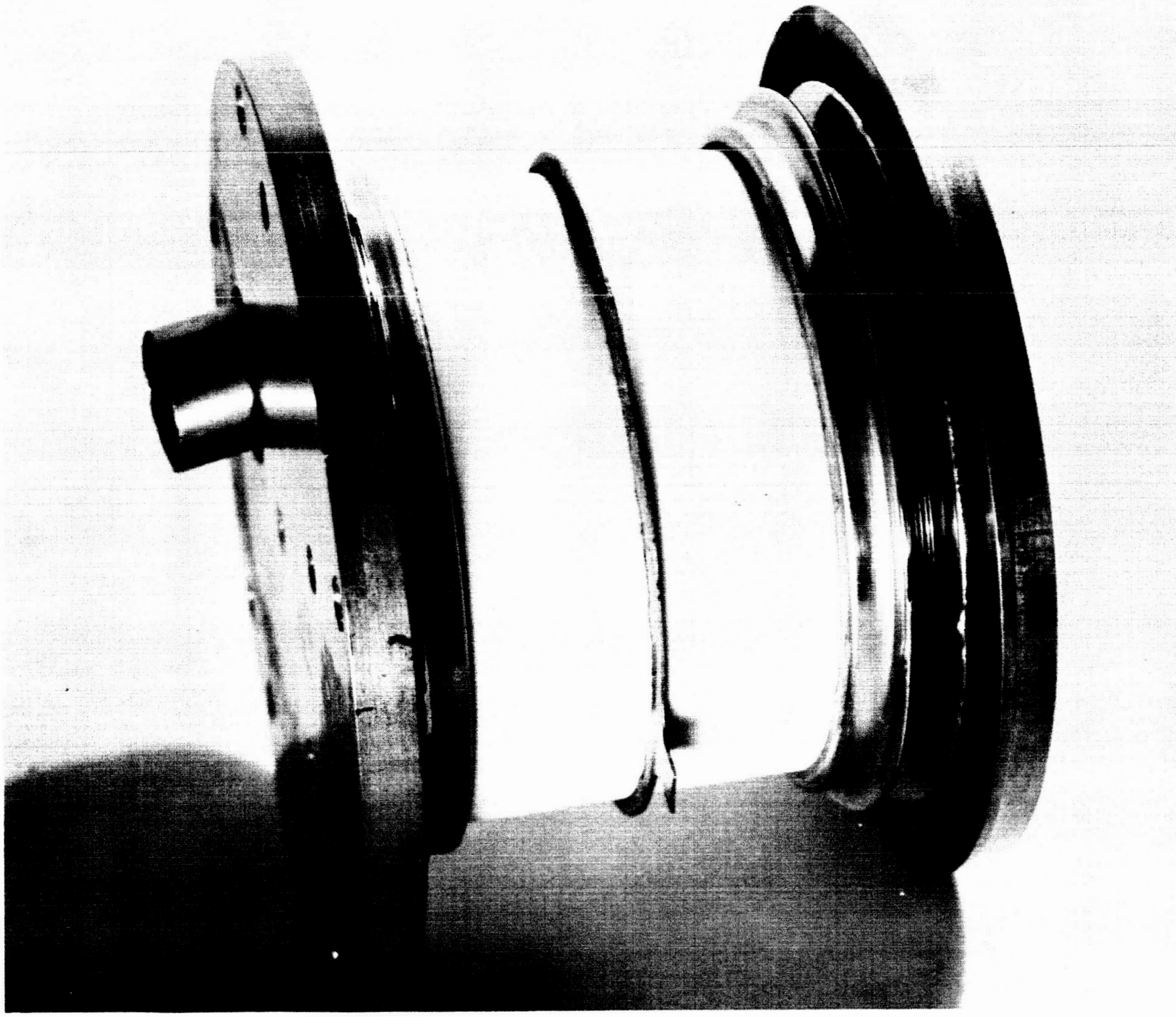


Figure 4. Vacuum Capsule Assembly Prior to Attachment of Ion Pump.

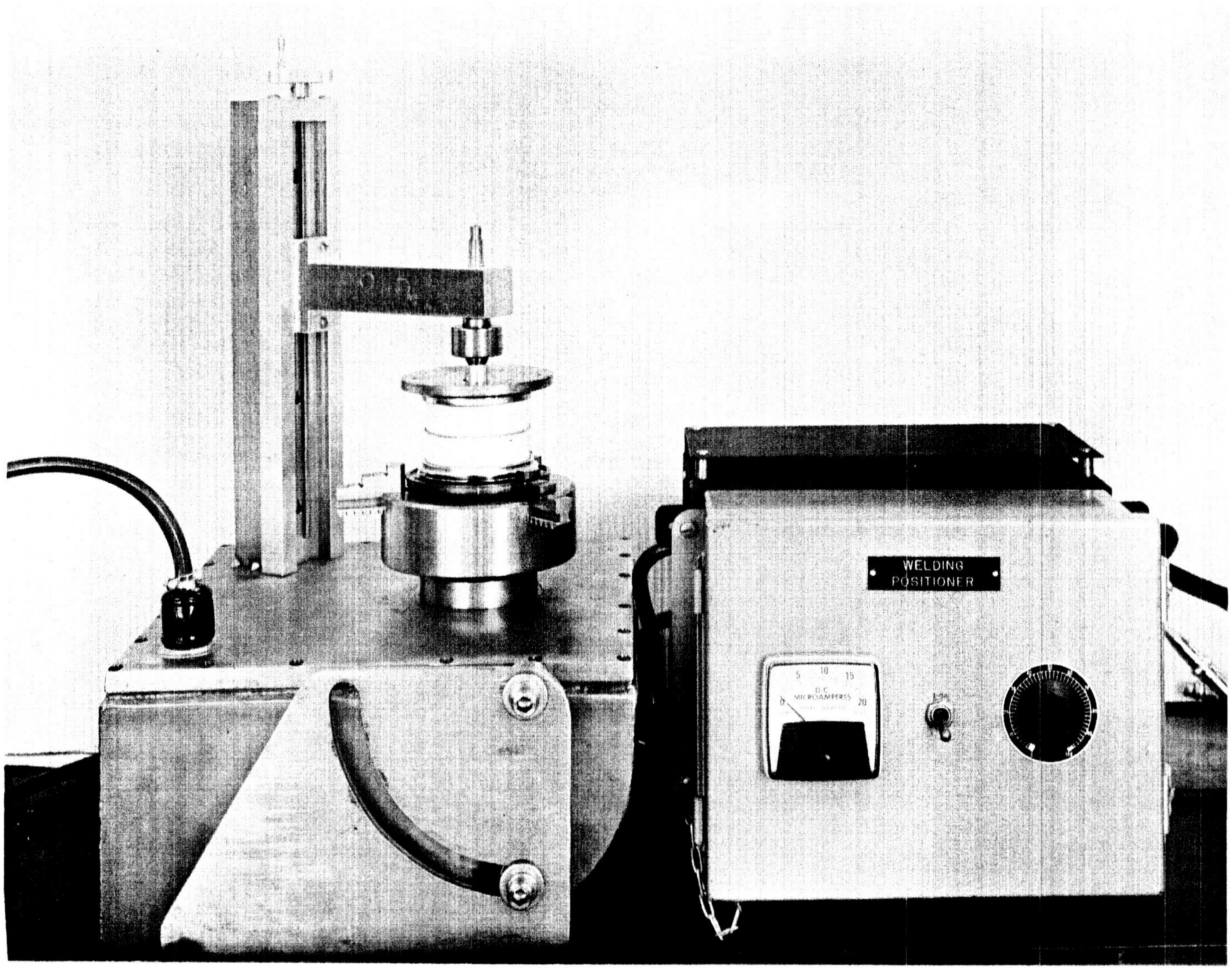


Figure 5. Rotating Fixture for Welding of the Three Seams in the Vacuum Capsule.

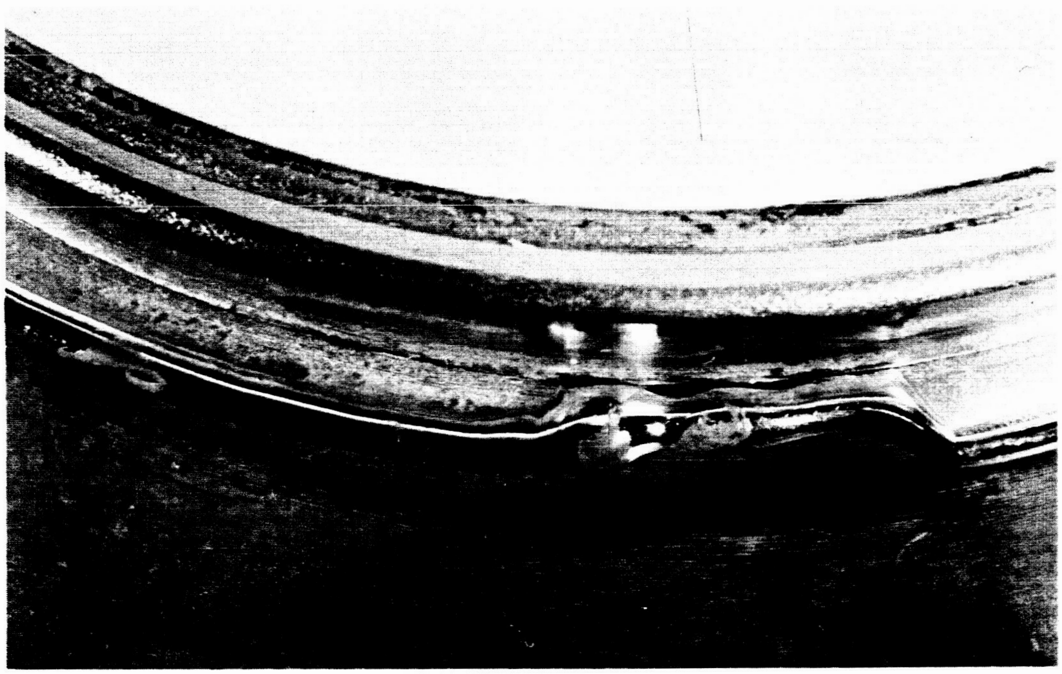
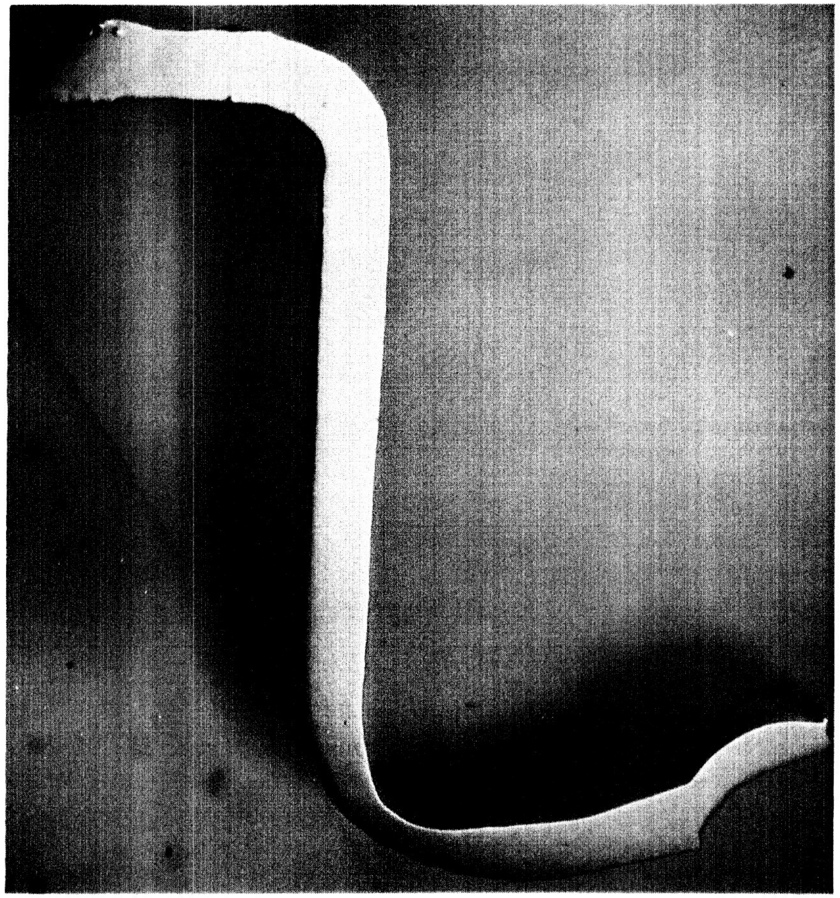


Figure 6. Welded Joint and Nearby Crack which Developed in Spinning of Ceramic Assembly.



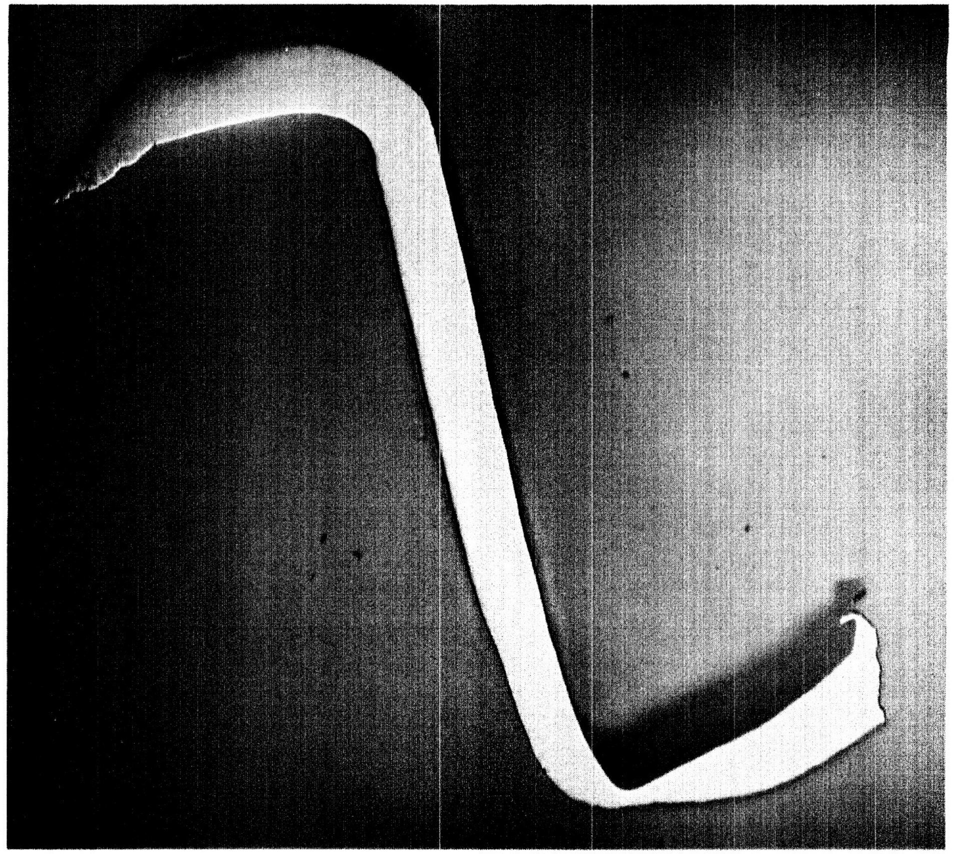


Figure 7. Cross-Sections of End Spinnings on the Ceramic Assemblies at 20X Magnification. Left View is Section of Top Spinning Attached to Bellows End of Capsule Showing that Original .020" Material was Reduced to Approximately 0.009" at Bend Near Weld. Right View is Section of Spinning at Lower End of Ceramic Assembly Showing that Thickness was Reduced to Approximately 0.005" at Bend Near Weld to Bottom Rodar Disk and Flange.

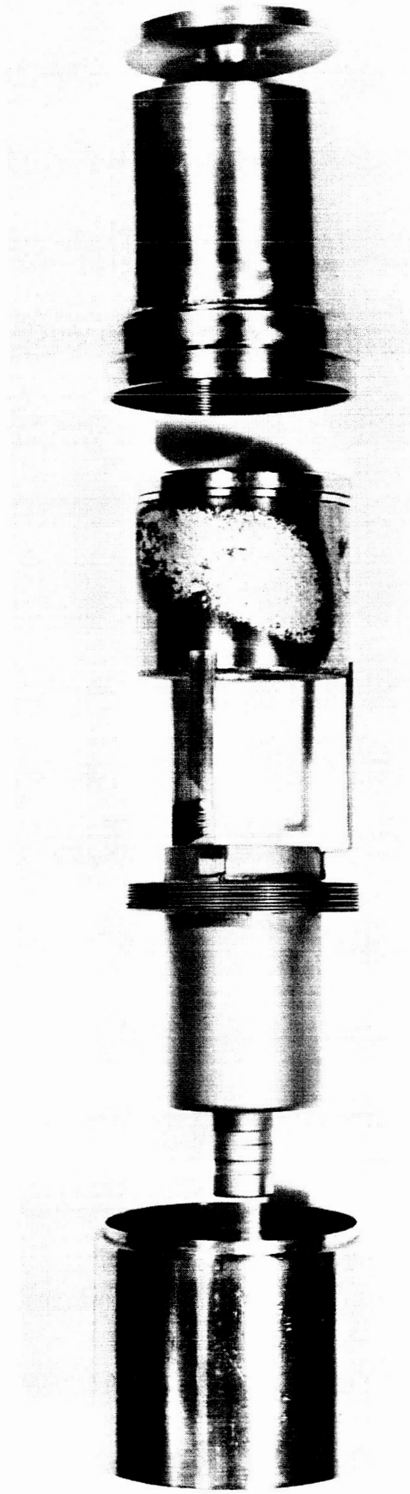


Figure 8. Parts of the Ion Pump Enclosure Prior to Assembly and Attachment to the Contact Capsule.

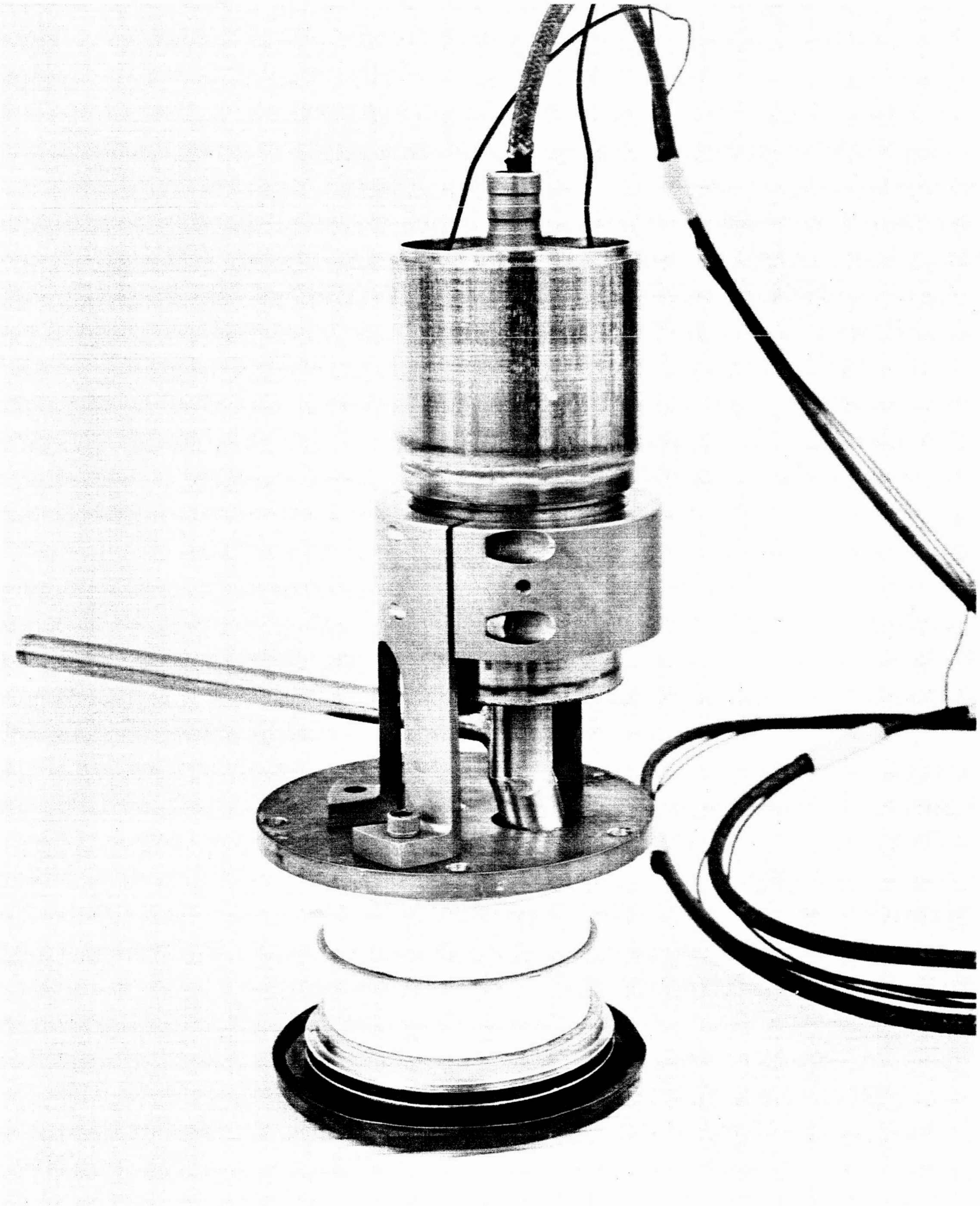


Figure 9. Vacuum Capsule with Ion Pump and Enclosure Attached and Welded Together.

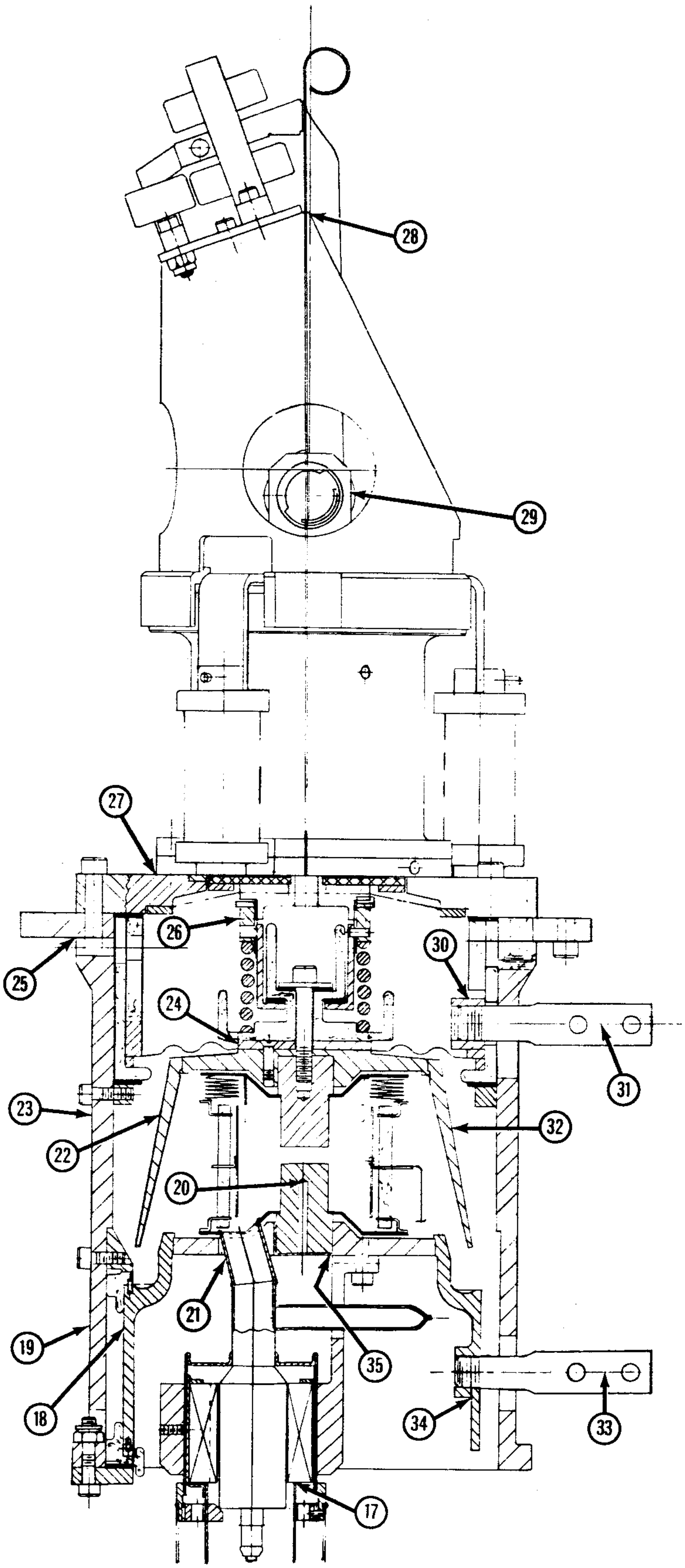


Figure 10. Cross-Section Drawing of AC Breaker with Vacuum Capsule in the Center and Radiators (#18 & #22) Attached for Heat Transfer.

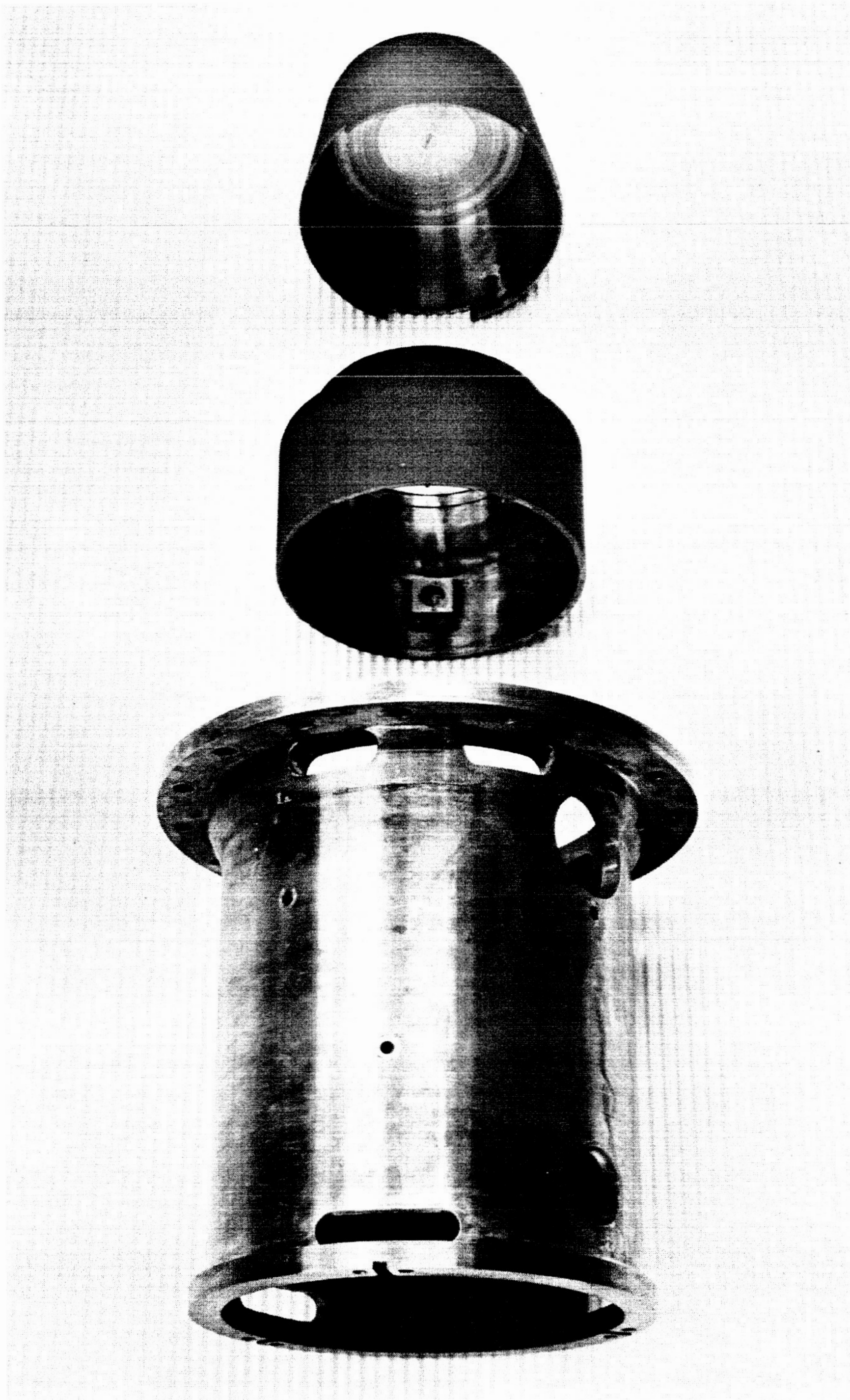


Figure 11. Interrupter Unit for AC Breaker, Including Upper and Lower Capsule Radiators, after Iron Titinate Plasma Spray Coating.

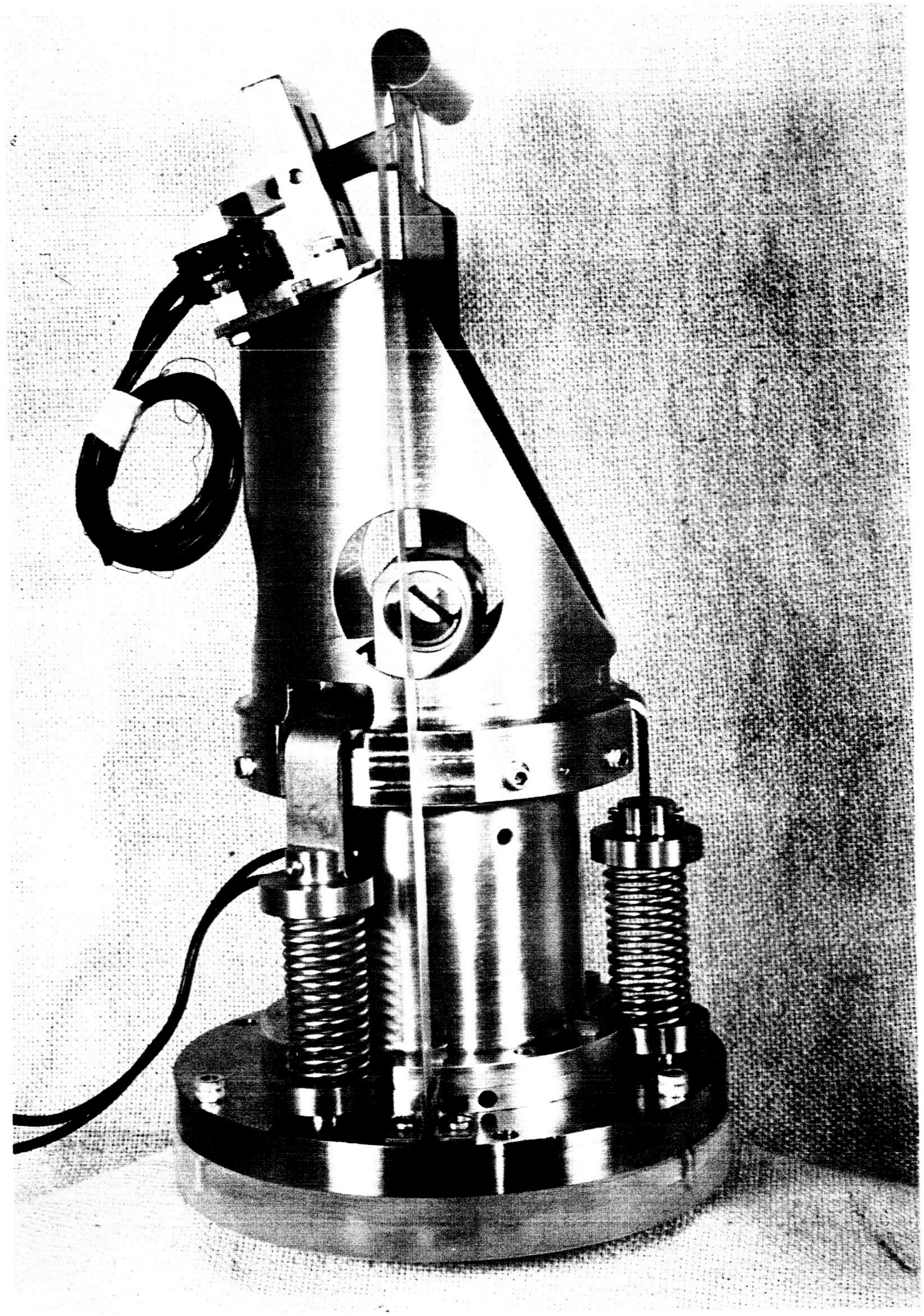


Figure 12. Actuator for Switchgear Units, in Closed Position, with Coils for Closing and Latching.

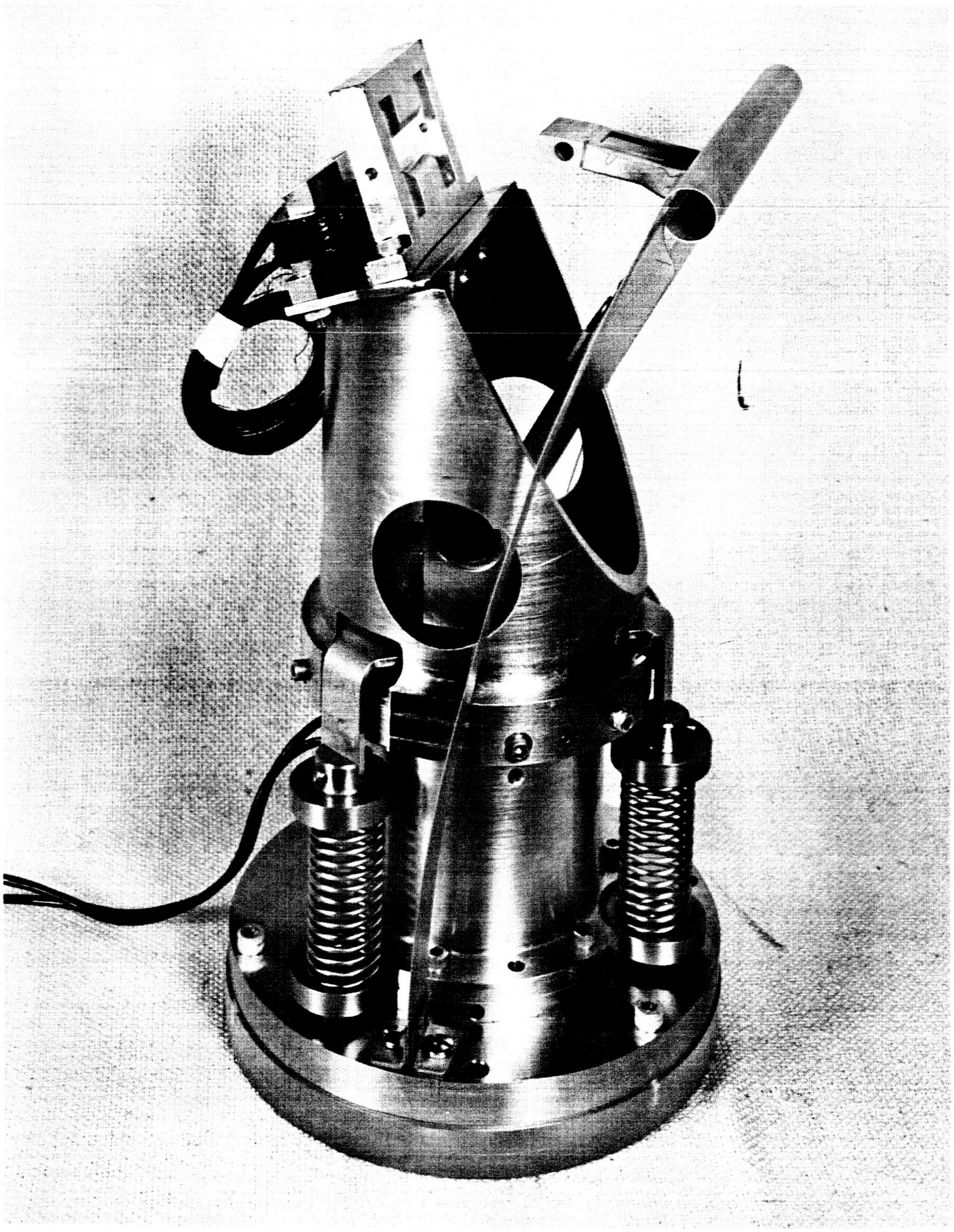


Figure 13. Actuator for Switchgear Units, in Open Position, with Latching Coil but not Tripping Coil in Place at Top of Assembly.

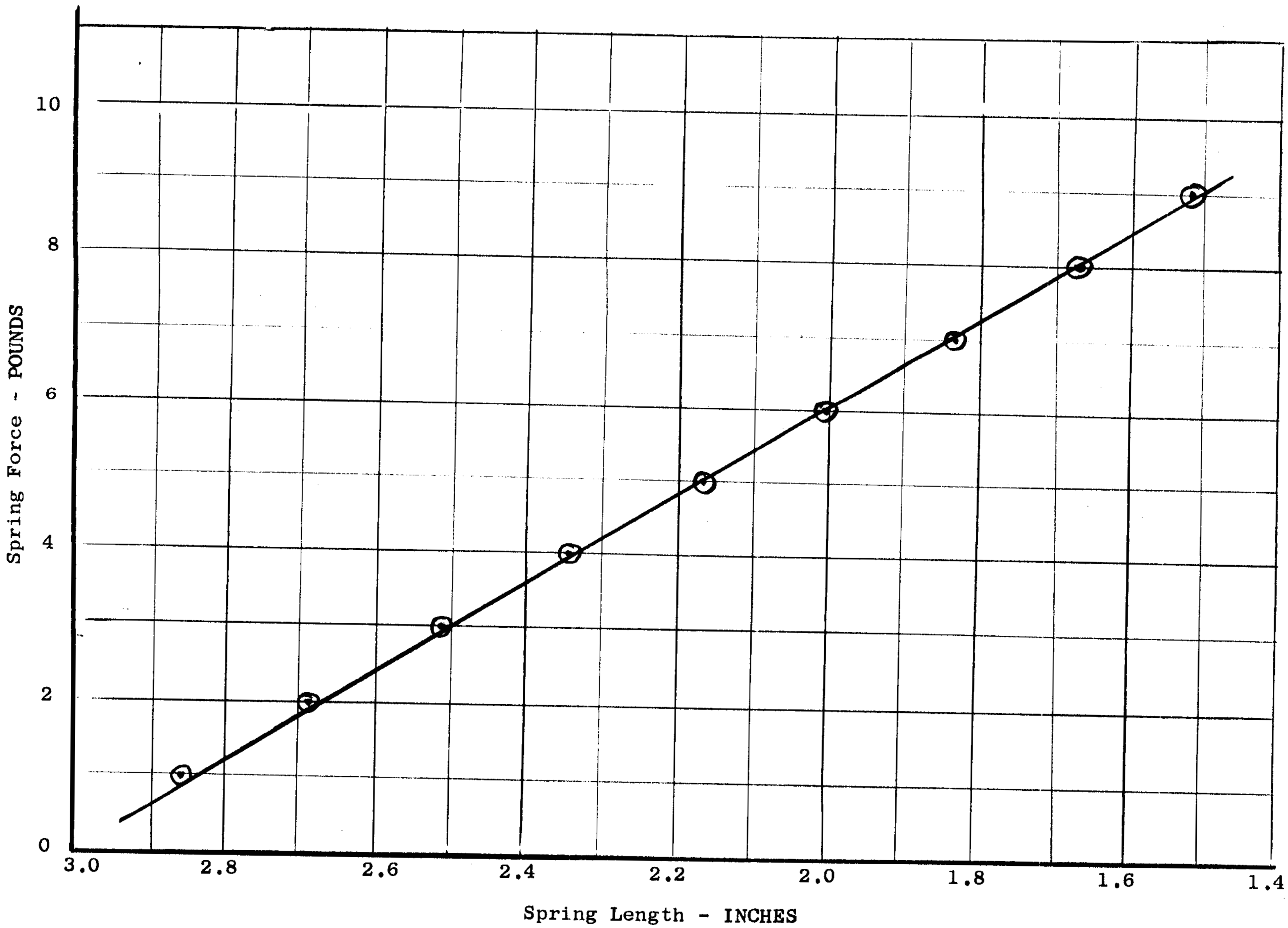


Figure 14. Calibration Curve for Opening Spring Used in Vacuum Environment.

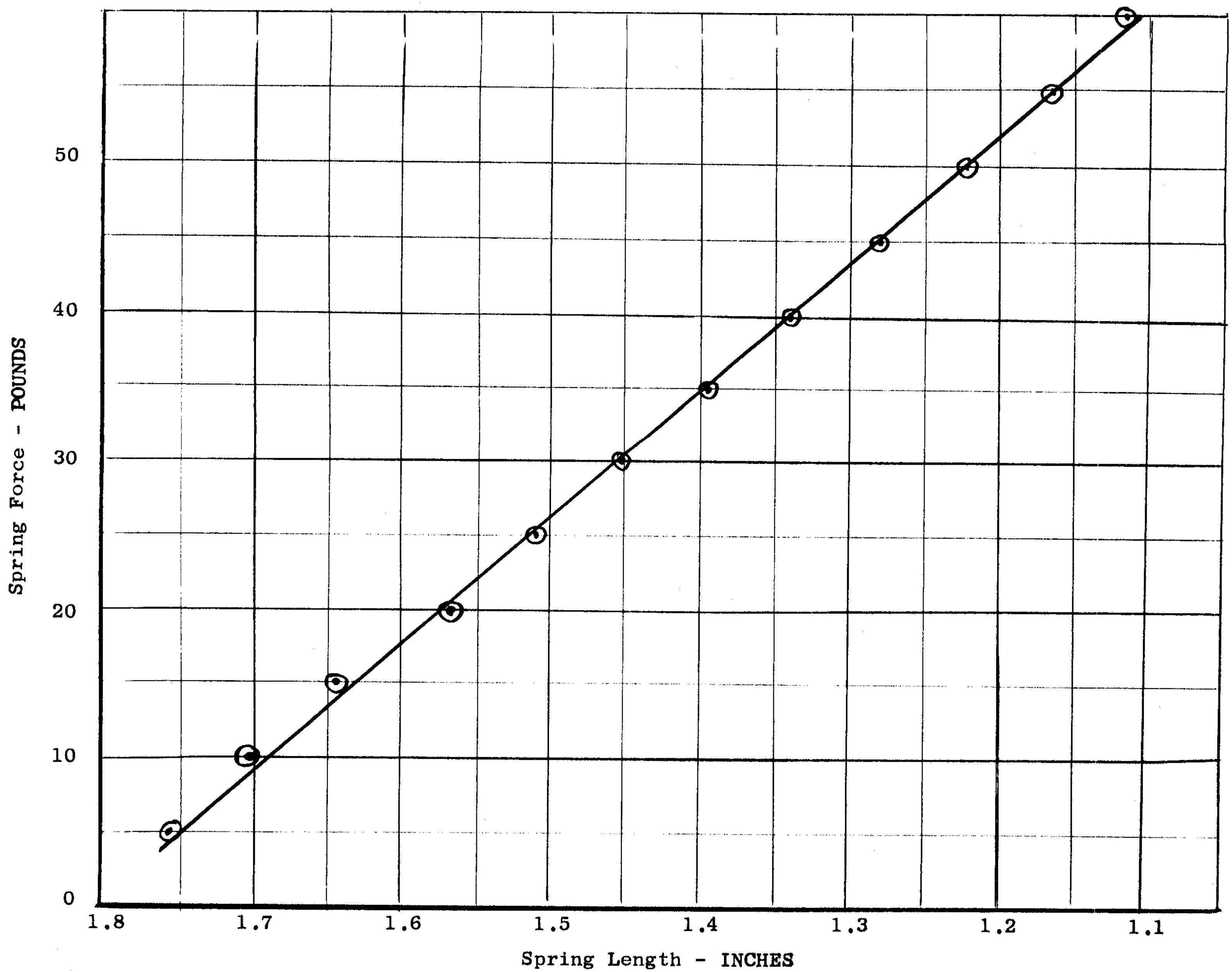


Figure 15. A.C. Circuit Breaker Contact "Wipe" Spring Calibration.

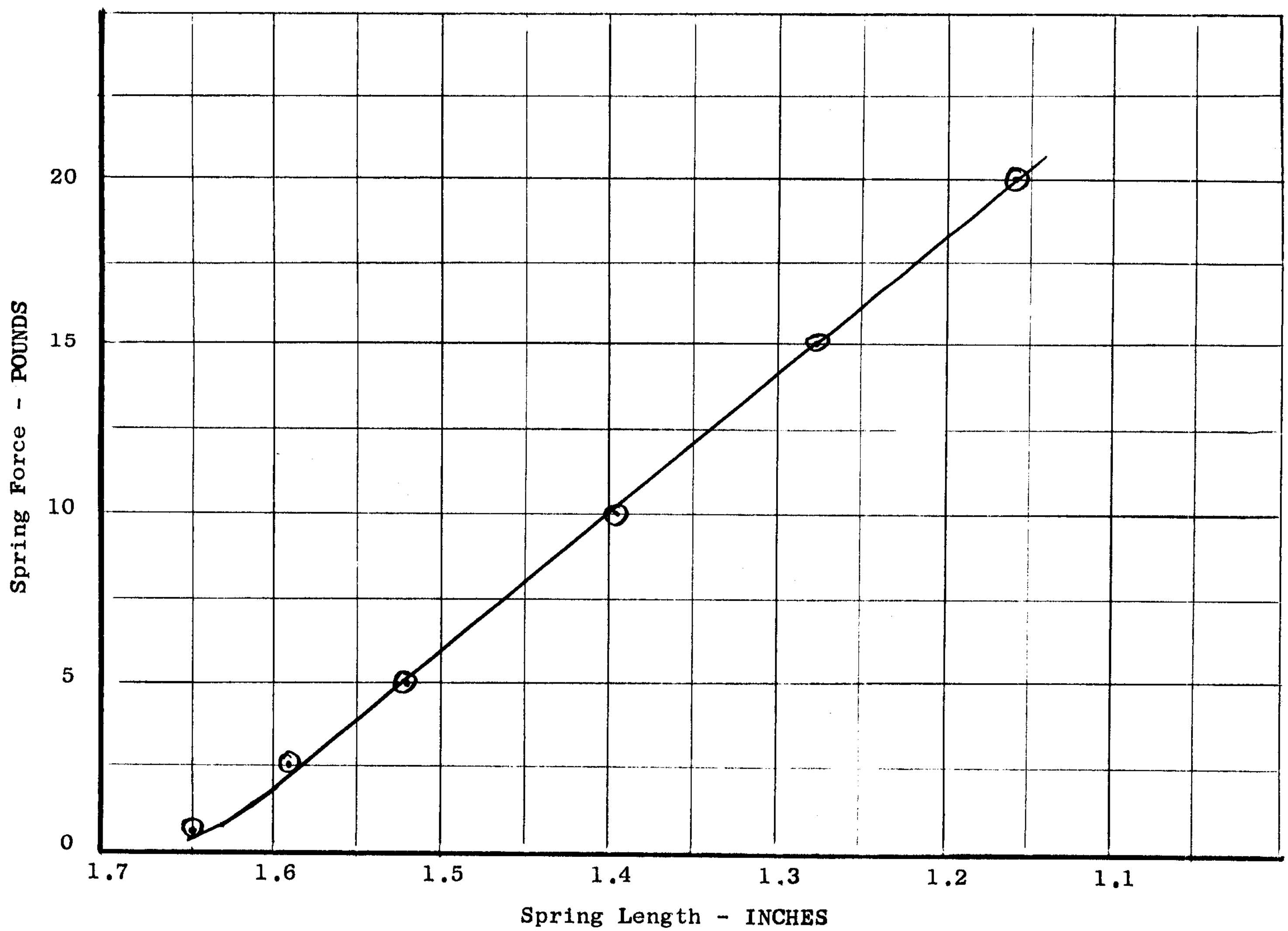


Figure 16. D.C. Engine Contactor Contact "Wipe" Spring Calibration.

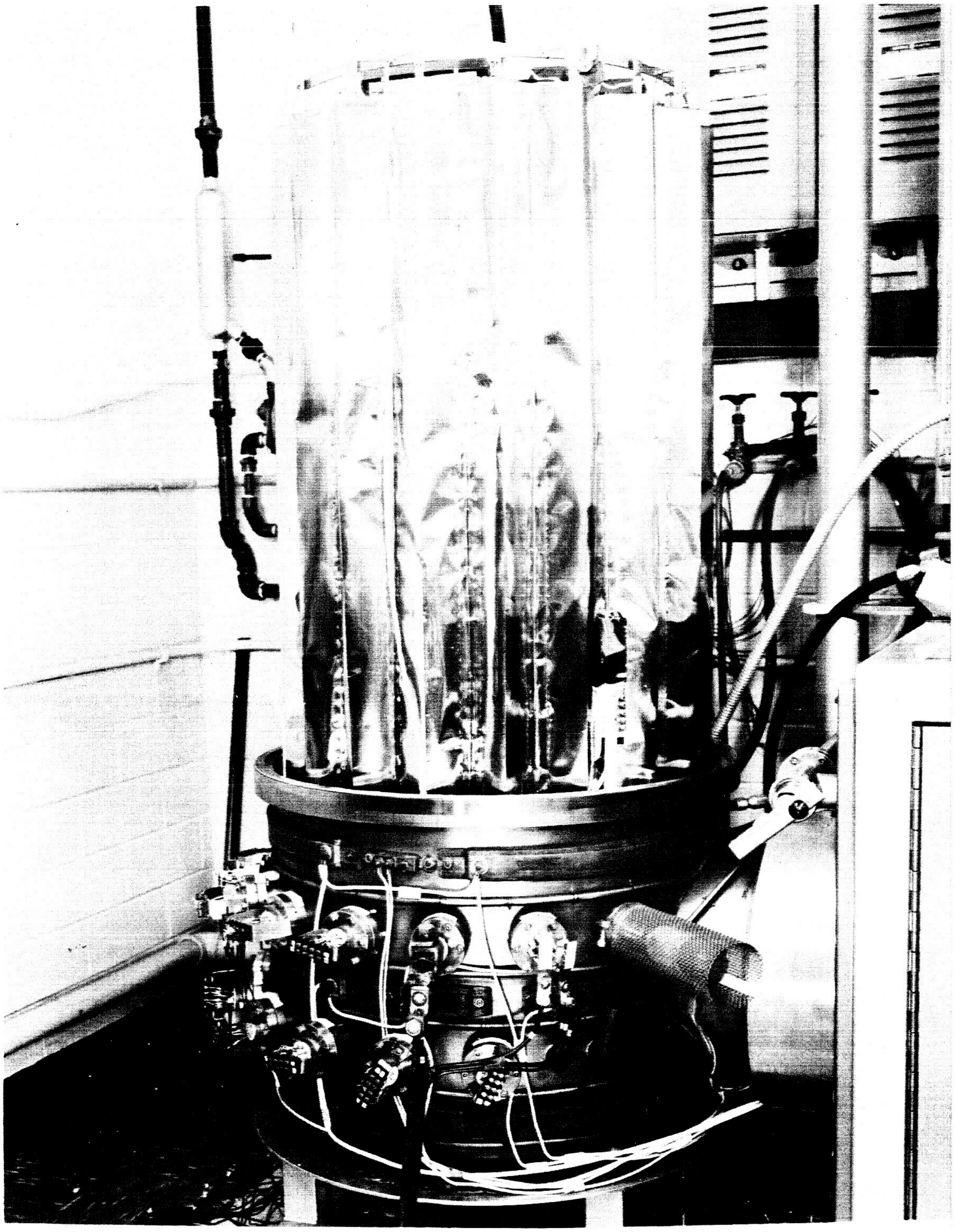


Figure 17. Switchgear Test Oven in Ultra-High Vacuum Tank with All Lamp and Thermocouples Connected, Just Prior to Installing Tank Lid for Bake-out Test.

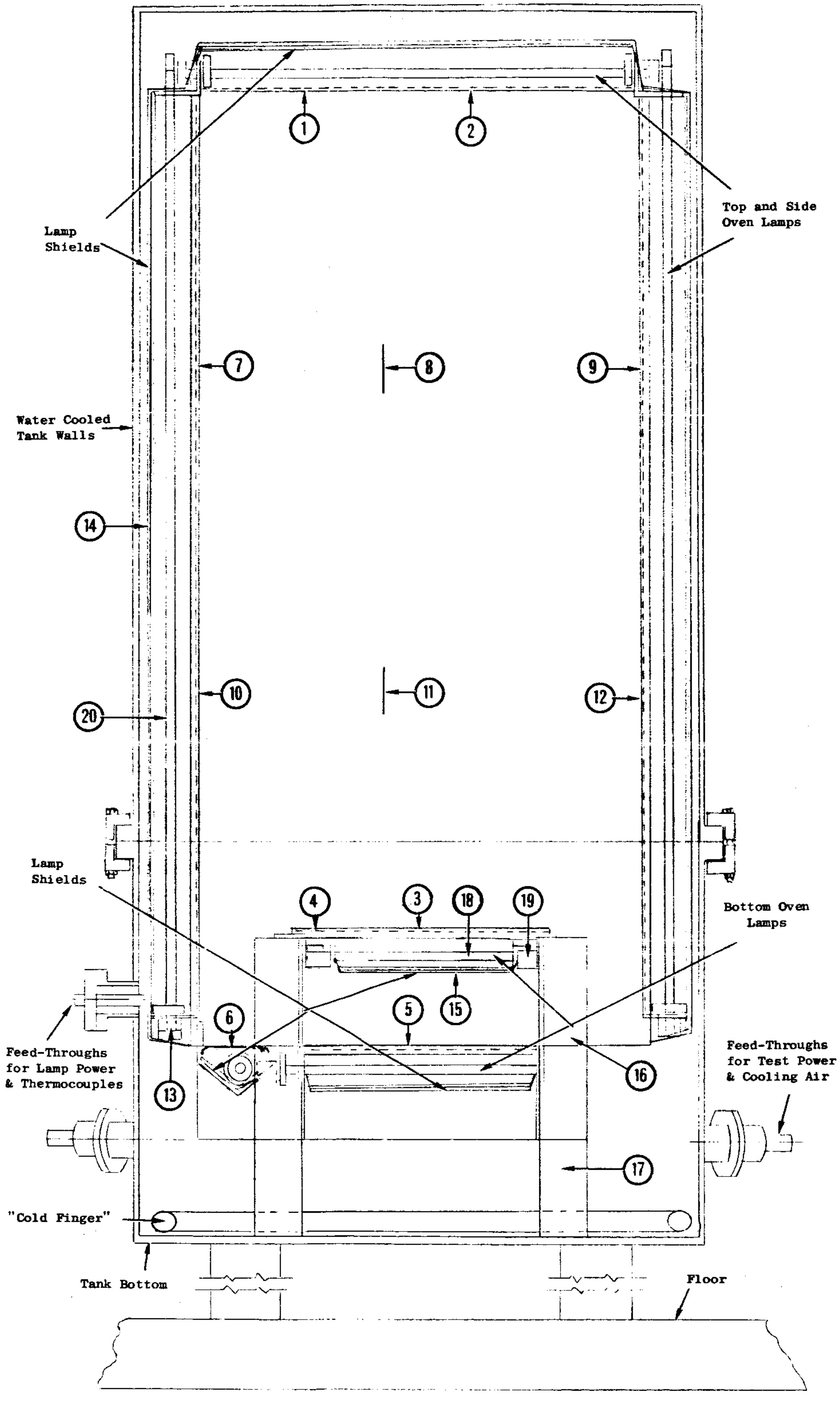


Figure 18. Sketch (Section View) of the Vacuum Tank and Oven for the Switchgear Tests, Showing Location of the Thermocouples Used for Initial Bake-out.

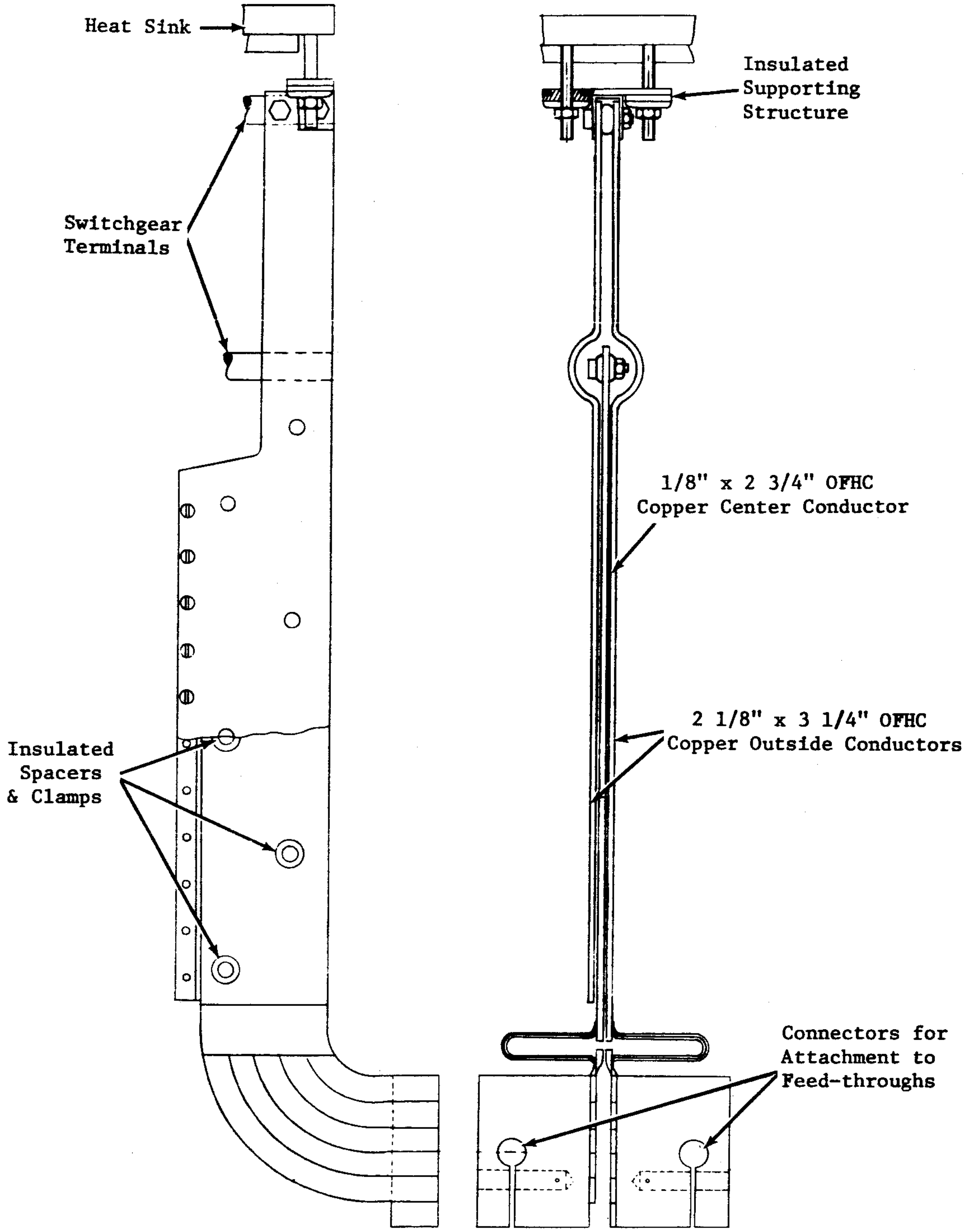


Figure 19. Sketch of Special High Current Laminated Conductor for 600 Ampere Use at 1000 to 3000 cps.

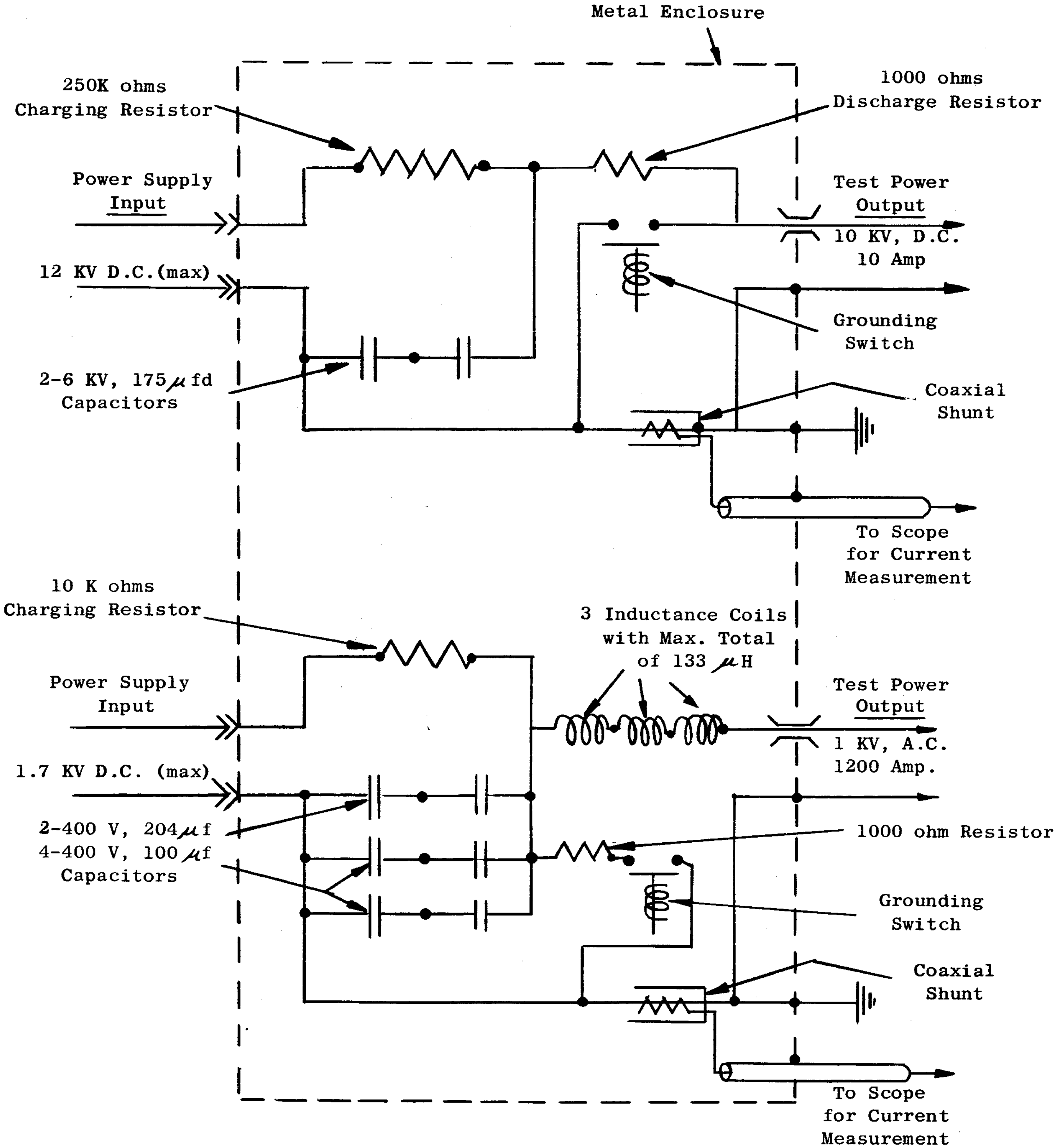


Figure 20. Schematic Diagram of Power Supply for A.C. and D.C. Interruption Tests.

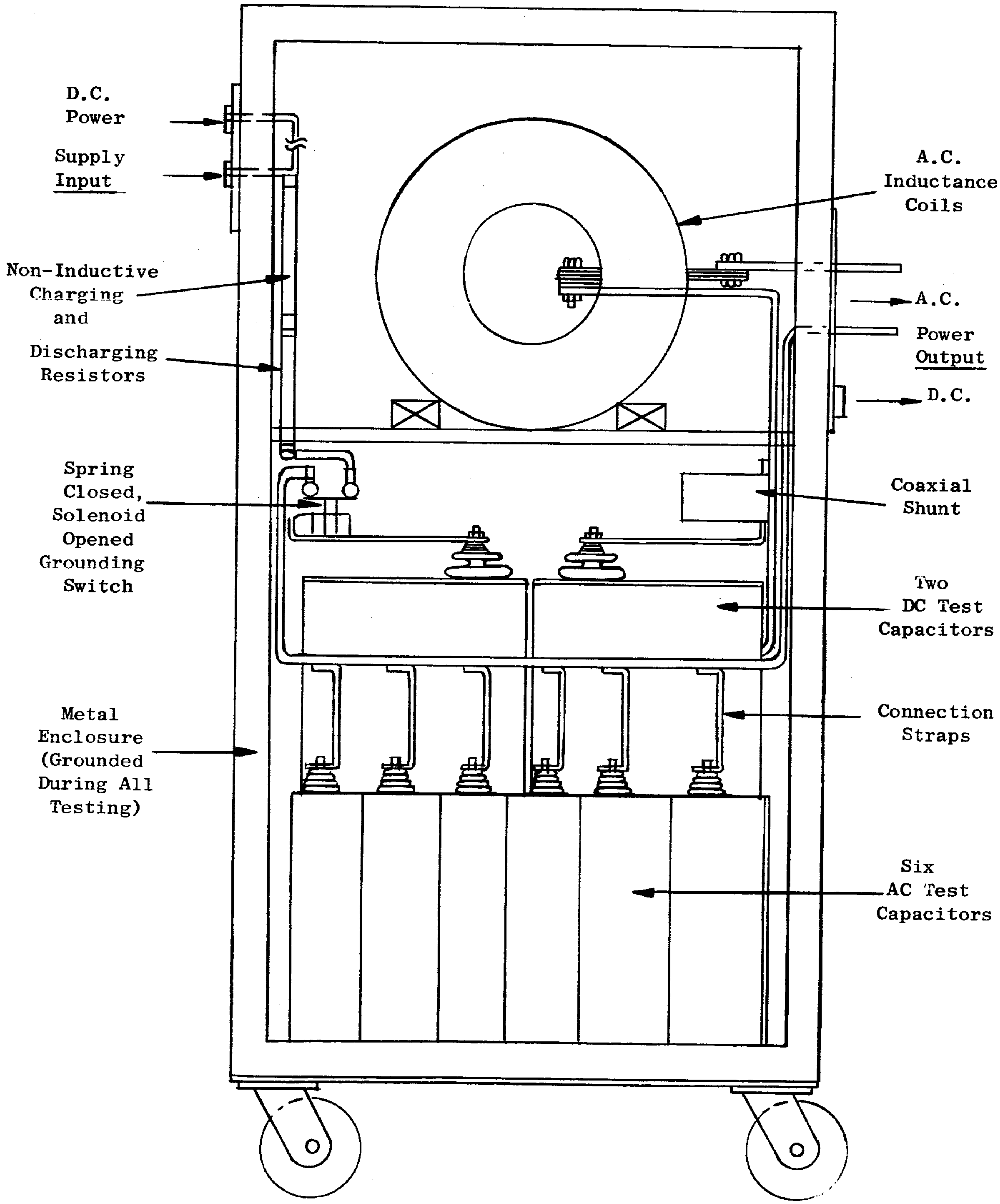


Figure 21. Layout of Proposed Interruption Test Power Supply Cabinet.

APPENDIX A

APPENDIX A

FABRICATION OF CONTACT CAPSULE ASSEMBLIES FOR HIGH TEMPERATURE SWITCHGEAR

A) Preassembly Inspection and Cleaning

All molybdenum contacts and Rodar dishes were examined by both "Dye-Check" penetrant and "Zyglo" penetrant inspection techniques for the presence of any surface imperfections. As a result of these inspections, one molybdenum contact and one Rodar dish were found to be defective; all others were acceptable. Visual examination (up to 10X) of the remaining components indicated no additional defective parts.

Prior to assembly, all parts were cleaned in accordance with SPPS specification 02-0136-00-A.

B) Fabrication - Welding and Brazing - End Pieces

The initial step taken in manufacturing the contact braze assemblies was the inert gas shielded, tungsten arc welding of parts # 3 and 7 of drawing 115A5166 (lower Rodar dish to 316 SS tube for eventual coupling with ion pump). Four such joints were made, after which the integrity of the welds was determined by visual examination and helium leak testing.

The techniques used in subsequent brazing of both the upper and lower contact assemblies were the same; once the correct method (temperature measurement, braze alloy, braze alloy positioning, part positioning) of brazing had been established through trials on one of the intended lower contact assemblies. Eight brazed assemblies were required (4 upper, 4 lower) for subsequent manufacture of four vacuum interrupter capsules. The following describes the procedures used and considerations taken which led to the successful fabrication of the necessary assemblies.

When considering Amzirc (zirconium diffused copper) for applications wherein superior strength characteristics are desired, as compared with unalloyed copper, one limiting factor is the potentiality of incipient melting occurring if exposure temperatures exceed 1795°F. Also, the maximum temperature expected in the vicinity of the brazed joints during operation of the switchgear was slightly in excess of 1500°F. Hence, the braze alloy selected to join the Rodar-Amzirc-Molybdenum components must have a melting point in the 1500°F to 1800°F temperature range and exhibit adequate solubility with each of the parts being joined to provide satisfactory bonds. The braze alloy originally selected to fulfill these functions was 82Au-15Cu-3Ni, melting point 1670°F, brazing temperature 1700°F.

The cleaned Rodar-Amzirc-Molybdenum components of the intended first lower contact assembly were positioned as per the engineering drawing and rings of the 82Au-15Cu-3Ni braze alloy were placed as required. The assembly was subsequently inserted in a zirconium enclosure or can, atop two L-605 support blocks. The zirconium can was lined with molybdenum foil to prevent intimate contact of the Amzirc flange with the zirconium can interior. A zirconium lid was then tack welded onto the can. The enclosed assembly was then exposed to a 1700°F/2 min. braze cycle, using a vacuum furnace wherein the pressure was maintained at less than 5×10^{-5} Torr during the heating and cooling cycles. Temperatures were measured by means of a Pt-Pt/10%Rh thermocouple inserted through the zirconium can and into a machined well in the base of the molybdenum contact.

Upon removal of the brazed assembly from the furnace, it was observed that the Au-Cu-Ni braze alloy had not properly wet the surface of the molybdenum contact. Because copper and gold exhibit little if any solubility with molybdenum, the primary alloying with this member was expected to be achieved by means of a nickel-molybdenum reaction. But the Au-Cu-Ni braze alloy contains only a 3% nickel addition which thus provided a plausible explanation for the poor wettability observed.

As a result of the above behavior, a different braze alloy was selected for fabrication of the contact assemblies. This alloy, 82Au-18Ni, has a significantly higher nickel content and had been initially considered as a prime candidate for use in manufacture of the capsules. However, normal brazing practices dictate that brazing temperatures should exceed the melting point of the braze alloys by 50°F to 100°F. Using the 82Au-18Ni alloy at such temperatures above its melting point (1760°F) would mean exposure of the Amzirc member of the assembly to a temperature higher than its incipient melting temperature. To overcome this problem, it was decided to attempt the brazing at a temperature only 25°F above the melting point of the alloy; i.e., 1785°F. A subsequent brazing cycle on a representative contact assembly using the 1785°F braze temperature proved to be quite acceptable from the standpoint of filleting and apparent flow of the alloy. All eight contact assemblies were thenceforth brazed with the gold-nickel braze alloy, using the techniques described previously for protection of the parts, alloy placement, and temperature measurement.

The lower contact assemblies (Serial #'s 2, 3, 4, 5) were all brazed satisfactorily, and post-braze helium leak testing of all assemblies indicated that no leaks were present. The only difficulty encountered was associated with the slight distortion of the thin (0.020 inch) Amzirc shelf in the lower flange, which resulted from the inability of this material to properly support the weight of the molybdenum contact while the assembly was at the brazing temperature

The upper contact assemblies (Serial #'s 1, 2, 3, 4) were brazed in the same manner as the lower assemblies; i.e., the Amzirc member was inverted from the position shown in drawing 115A5166, prior to insertion of assembly in the zirconium envelope. The upper Rodar shields (part # 11) were also brazed to the upper Rodar dishes (part # 10) with the 82Au-18Ni braze alloy simultaneously during the individual braze cycles. Upper contact assemblies (Serial #'s 3 and 4) were brazed satisfactorily; visual examination and helium leak testing indicated no flaws. Assembly, Serial # 2, also brazed satisfactorily; however, the molybdenum contact surface was not parallel with the Amzirc flange base and it was necessary to reface that contact surface to attain an acceptable degree of parallelism. After the initial braze cycle on upper contact assembly, Serial # 1, it was observed that the Rodar dish had become tilted on the shoulder of the molybdenum contact, necessitating a rebraze cycle to correct the misalignment. The rebraze cycle was successful in realigning the Rodar dish; however, excessive erosion of the dish produced a small leak through the joint as indicated by helium leak testing. To achieve a vacuum tight assembly, a third braze cycle was used. A ring of the 82Au-15Cu-3Ni braze alloy was placed over the fillet formed by the 82Au-18Ni braze and the assembly rebrazed at $1700^{\circ}F$/3 min. Helium leak testing of this assembly after the third braze cycle indicated no leaks present. It was also observed that the surface of the molybdenum contact was not parallel with the

Amzirc flange base; hence, the contact surface of upper contact assembly, Serial # 1, was also refaced.

At the completion of this brazing portion of the capsule assembly, 10X photographs were taken of the mol·bdenum contact surfaces (both upper and lower) for use in comparison checking with the same contact surfaces after all electrical testing had been completed.

C) Fabrication-Welding of Seal Assembly

One each of the upper and lower contact braze assemblies was positioned along with a bellows and a metal to ceramic seal assembly, as per drawing # 115A5168, in a special fixture used to maintain alignment of these components while permitting their rotation during welding. The initial step taken in this final assembly was to spot tack weld each member to the next adjacent member; after which the entire fixture was rotated 90 degrees to a horizontal position. Subsequent tungsten arc welding of the contact capsules was conducted in a vacuum purged weld chamber which had been back filled with argon gas. Post-weld helium leak testing of this first capsule indicated leakage less than 5×10^{-10} std. cc/sec of air. However, visual examination did indicate that resistance spot tacking had produced small craters in the rodar components. To eliminate these craters the components of the three remaining capsules were initially TIG tack welded together before rotation of the fixture. These TIG tack welds, as well as the final welding, were all conducted in the previously mentioned vacuum purged, inert gas weld chamber.

APPENDIX B

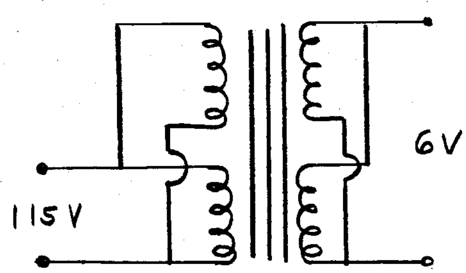
TEST & INSPECTION PLAN	NO. TIP # 2
PART NO. & NAME Switchgear Testing Transformer	CONTRACT NO. NAS 3-6467
VENDOR Nothelfer Winding Laboratories, Incorporated	PURCHASE ORDER NO. 037-127740

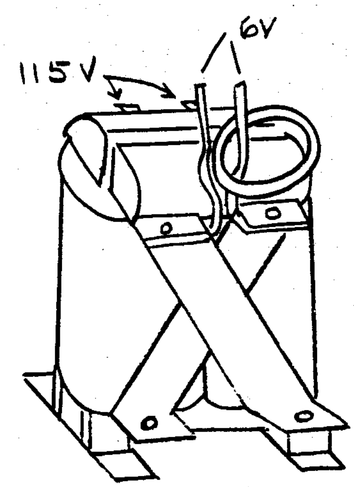
Results of Transformer Testing

The transformer has been tested under various conditions and the results are tabulated below:

f cps	V_{pri} volts	I_{pri} amps	V_{sec} volts	I_{sec} amps	V_{sec} (no load) volts
1000	115	33	4.8	625	5.4
2000	115	33	4.8	630	5.4
3000	115	25	4.8	465	5.4
3000	150	30	6.4	575	---

Construction of transformer





Ratings: 3.6 KVA, f = 1000 to 3000 cps
V_{pri} = 115 volts, V_{sec} = 6 volts.

The transformer does not meet the specifications. However, by increasing the primary voltage the required KVA can be obtained.

Instruments used for test were:

Behlman variable frequency power supply
GE 5 amp. thermocouple ammeter
Weston current transformer

FORMAT	PREPARED BY	
I. Characteristics to be checked. II. Methods and/or equipment to be used for checking (including calibration and evironmental controls where needed). III. Material and processing requirements. IV. Spaces for recording results.	George Gati George Gati SIGNATURE	2/8/66 DATE

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